Magnetic Field Effects on Spark Ignition Engine Performance and its Emissions at High Engine Speeds

Ph.D(Lecturrer) Mohammed.A.Al-Rawaf

Al-Mansour University Collage
Baghdad, Iraq

Abstract

The present work deals with the effect of the magnetic field on the performance of (spark ignition engine). Thermal efficiency, brake specific fuel consumption (bsfc) and exhaust emissions were measured for Iraqi gasoline which has octane number of (83). The fuel was subjected to a magnetic field of (1000 and 2000 Gauss), respectively. The magnetic field was placed on fuel supply line to magnetize the fuel before admitting it to the carburetor. Mercedis Benz SI engine, 4 strokes, and 4 cylinders were used in this study under engine speed ranging between (2000 to 3500 rpm) at maximum load.

A reduction in fuel consumption up to (2.19%) and (5.488%), brake thermal efficiency rose by about (4.7%) and (13.5%), for one and two magnets, respectively. The exhaust gas emissions showed a reduction in CO nearly by (3.7%) and (6.9%), CO_2 up to (3.43%) and (9.2%). However the exhaust temperature increased up to (1.7%) and (3.65%) for the two magnets values, respectively.

Keywords: Magnetic field, magnet, brake power, thermal efficiency, CO, HC, CO_2

تأثير الفيض المغناطيسي على أداء وملوثات محرك ألأشتعل بالشرارة يعمل عند سرع عالية

م.د.محمد عبدالكريم الرواف

كلية المنصور الجامعة، بغداد، العراق

الخلاصة

في هذا العمل اجريت دراسة تأثير المجال المغناطيسي على اداء محرك يعمل بالشرارة حيث، تم قياس القدرة المكبحية والكفاءة الحرارية والأستهلاك النوعي المكبحي للوقودوملوثات العادم لوقود جازولين عراقي ذي رقم أوكتاني 83، وتم تسليط فيض مغناطيسي على الوقود (1000 و 2000 جيس) على التوالي. تم تركيب الفيض المغناطيسي على خط تجهيز الوقود لمغنطة الوقود قبل دخوله الى المفحمة. تم استخدام محرك مارسيدس بنز ذو أربعة أشواط وأربعة اسطوانات في هذة الدراسة وبحدود سرع محرك تتراوح بين 2000 الى 3500 دورة/دقيقة) عند أقصى حمل.

تم الوصول الى انخفاض في استهلاك الوقود يصل الى (%2.19) و (%5.488)، وارتفعت الكفا ءة الحرارية المكبحية بحدود (%4.7) و (%13.5) عند استخدام مغناطيس واحد ومغناطيسين على التوالي.
أظهرت ملوثات غازات العادم نقصانا في تراكيز CO بحدود (%3.7) و (%6.9)، وزادت تراكيز CO_2 بحدود (%3.43) و(%9.2)، كما أن درجات حرارة الغاز العادم زادت بحدود (%1.7) و (%3.65) لمغناطيس واحد ومغناطيسين على التوالي.

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الكلمات المفتاحيه:الفيض المغناطيسي،مغناطيس،القدره المكبحيه،الكفاءة الحراريه , CO_2،HC,CO

1. Introduction

Today's hydrocarbon fuels deposit carbon residue that clogs carburetor and fuel injector. This will lead to reduction in efficiency and wasted fuel. Pinging, stalling, loss of horsepower and greatly decreased mileage on cars are very noticeable [1]. Low efficiency of combustion heat, unburned fuel and air pollution (like CO, NOx, SOx and soot) are still problems [2] .One of the techniques that lead to increased efficiency and reduced emission is the "magnetization of the hydrocarbon fuel molecules". This is achieved by exposing the fuel to a permanent magnetic field [3].

It is well know that hydrocarbon have long branched geometric chains of carbon atom. This has a tendency to fold over onto themselves and on adjoining molecules this is due to intermolecular electromagnetic attraction existing between them [4]. Van der Waals was the first who applied a magnetic field to fuel molecules and found out that the viscosity of the fuel decreases with the application of the field and consequently an increase in the flow rate of the fuel. This is because in most cases, all substances according to faraday are affected by a magnetic field though. This influence may be insignificant [5]. Fuel molecules subjected to external magnetic field, are usually excited, which in turn causes mole reorientation in order to accommodate the applied external magnetic field. The above phenomenon is attributed to the fact that on the molecular level, a spinning electron is subjected to precise amount of electromagnetic energy absorbing that energy and spin-flip into an aligned state [6].

Al-Mosawi [7], studied the effect of octane number of the fuel on the performance of the spark ignition engine. The study included the fuels with octane number (70, 75, 80, 85 and 90). The results showed that the engine performance is increased step by step according to the increasing of the octane number of fuel. At engine speed of 2800 rpm, the torque and the brake thermal efficiency were increased by 9.75% and 12.48%, respectively. While at engine speed 3400 rpm, the brake power and exhaust temperature were increased by (8.97%) and (3.7%), respectively. Also, the brake specific fuel consumption is decreased by (15%), at 2800 rpm.

Al Dossary, 2009 [8], concentrated in his study on engine performance by examining fuel consumption and exhaust emissions. The magnetic field was applied to the fuel supply line of a typical SI engine using unleaded gasoline fuel. Moreover, the magnetic field was generated by electromagnets with a twelve volts car battery while varying the strength and configuration of the magnetic field. The magnetic effect on SFC reduction was only consistently significant at the lowest load of 20 Nm and both speed extremes of 1000 and 3000 rpm using one magnet. The effect on CO was the most significant reduction of all other emissions at most engine's loads and speeds, especially at lowest speed of 1000 rpm using five magnets. The effect on NOx was the most consistent reduction of all others especially with the using the 'Spiral' configuration at lowest speed of 1000 rpm.

Okoronkwo, 2010 [2], presented a comprehensive experimental study on the effect of electromagnetic field on the ionization and combustion of fuel in an internal combustion engine. The obtained results during the test, gave a 50% reduction in the hydrocarbon constituent of the exhaust product in PPM and 35% reduction in the carbon monoxide. These results clearly indicate that the introduction of an electromagnetic field within the fuel line of an I.C engine enhances the combustion process thereby economizing fuel consumption and reducing gas emission making it environmental friendly engine.

Habbo et al., 2011 [9], carried out their studies to examine the effect of the magnetized fuel on both, the spark ignition engine performance and the exhaust emission. The experiments included submitting the fuel to magnetic field which was placed to fuel supply line to magnetized the fuel before entering the engine cylinder. Two types of magnets coils were used: the first one with 1000 Gauss and the other one with 2000 Gauss. The experimental tests were conducted at a speed of 2000 rpm, and a compression ratio of 8, wide open throttle (WOT).The results showed a considerable improvement in the engine performance. The thermal efficiency and engine power were increased by (4%) and (3.3%) respectively and a reduction in the specific fuel consumption by (12.8%) was achieved when magnet coil of 1000 Gauss was used and when a magnet coil of 2000 Gauss was used. The thermal efficiency and brake power were increased by (7.6%) and (16.4%), respectively. The specific fuel consumption was decreased by (21.3%) in comparison with no magnetic field case. The exhaust gas emission showed a reduction nearly of (80%) of CO and (44%) of HC when the magnetic coil of 1000 Gauss was used . Further reduction nearly by (90%) of CO and by (58%) of HC when the magnetic coil of 2000 Gauss was used.

The experiment of Faris et al., 2012 [10], was used to compare the effect of the magnetic field of a different intensity. These were (2000, 4000, 6000 and 9000 Gauss) Which was installed on the fuel line of two-stroke engine work with Iraqi gasoline on the fuel consumption and emission of exhaust gases. The results were good, as it was lead to reducing fuel consumption ranging between (9-14%). The highest reduction ratio was when using magnet with the intensity of 6000 Gauss as well as the intensity of 9000 Gauss. The results showed that the exhaust gas components (CO, HC) were decreased by 30% and 40% respectively, but CO_2 percentage was increased by 10%.

The aim of this paper is to study the effect of magnetic field on fuel consumption and polluting emissions, such as (CO and CO_2). This was accomplished for Iraqi gasoline fuel of octane number (83) by the magnets installed at the entrance of the carburetor of (S. I. engine), 4 strokes, 4 cylinders. Then, the results with and without applying magnetic field were compared.

2.Experimental Rig and Measuring Devices;

The engine used in the experimental work is spark-ignition engine Mercedes-Benz (200), 4-stroke, 4 cylinders. The displacement volume for this engine is 2 liters. The engine was coupled to a hydraulic dynamometer to measure the brake torque. **Figure** (1) shows the experimental rig of the engine, and **table** (1) lists the main technical specifications of this engine.

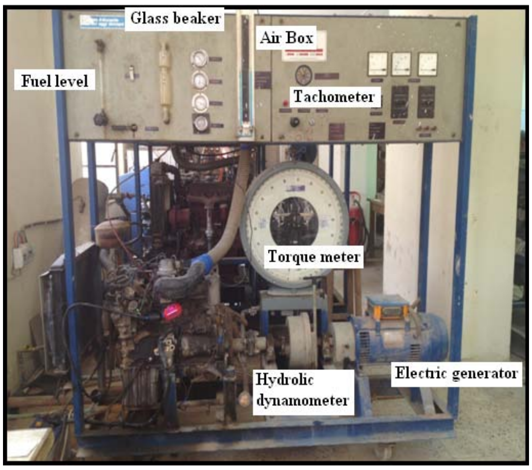

Fig. 1, The Experimental Spark

The hydraulic dynamometer type (isi lingegneria didattica) was used to measure the brake torque of the engine by using friction fluid. Water was used as the friction fluid. Engine speed was monitored by using an analogue tachometer type (VDO). A glass tube was utilized to measure the fuel consumption of the engine. This glass tube has a constant volume 100 ml, and a stop watch was used to measure the fuel consumption of this volume.

Table 1: The main technical specifications of the engine

Item	specification
Engine	4-cylinder-inline engine (four-stroke)
Displacement	2 liters
Fuel System	Carburetor
Cooling	Water

The supplied air to the engine was measured using air box. This is used to reduce the fluctuations, orifice and the manometer used to measure the pressure differential between the atmosphere and pressure inside the air box.

The exhaust gas analyzer type (mod 488 Italy) was used to analyze the emissions of exhaust. The analyzer detects the CO, CO_2, HC and O_2 contents. The gases are picked up from the engine exhaust pipe by means of a probe. They are separated from the water moisture through the condensate filter, and are conveyed then into the measuring cell. A ray of infrared light, generated by a transmitter, is sent through the optical filters onto the measuring elements. The gases in the measuring cell absorb the ray of light at different wavelengths, according to their concentration. The H_2, N_2 and O_2 gases due to their molecular composition (they have the same number of atoms), do not absorb the emitted ray. This prevents measuring the concentration through the infrared system. The CO, CO_2 and HC gases thanks to their molecular composition and absorbs the infrared rays at specific wavelengths (absorption spectrum). However, the analyzer is equipped with a chemical-kind sensor through which the oxygen percentage (O_2) is measured. Fig. 2 represents a photo of the exhaust gas analyzer type (mod 488 Italy).

.Fig. 2: The Exhausts Gas Analyzer Type

Two types of Magnetic devices with intensity of (1000) Gauss for each were used in this research. The first one was manufactured in the USA as shown in figure (2). The other one was manufactured in china. Fuel is subjected to the lines of forces from permanent magnets mounted on fuel inlet lines. The magnets for producing the magnetic field is oriented so that its South Pole is located adjacent the fuel line. Moreover, and its North Pole is located spaced apart from the fuel line. The magnetic field is applies for ionizing fuel to be fed to combustion chamber. Figure (3) shows the magnets installed in the fuel supply pipe.

Fig.3, Magnet Used in the Study

Fig. 4, Magnets Installed in the Fuel

3.Eoperimental Procedure;-

To ensure that all the data read from the measuring devices are correct, a calibration was executed using the following devices;-

(i). Tachometer

The linear method was used to calibrate the speed measuring instrument. A measured speed by a tachometer type (VDO) setup in the the experimental rig was compared by a diagrammatic speed that was obtained from another tachometer type (gas analyzer) which can also be used for measuring the engine speed by attaching an inductive clip-on pickup to a spark plug cable. The results were compared and plotted, as shown in figure (4).

(ii). Hydraulic Dynamometer

The measuring of brake power was conducted by using the hydraulic dynamometer, which was calibrated by using an electric generator dynamometer.

(iii). Exhaust gas temperature

Exhaust gas temperature was measured by the means of thermocouples type K. The thermocouples were calibrated using a standard thermometer. The thermocouple and a standard thermometer are inserted in a vessel filled with distilled water. This vessel was heated using an electric heater with heat regulator to change the water temperature. The water temperature was read before heating with both thermometer and thermocouple and the two readings are compared for calibration.

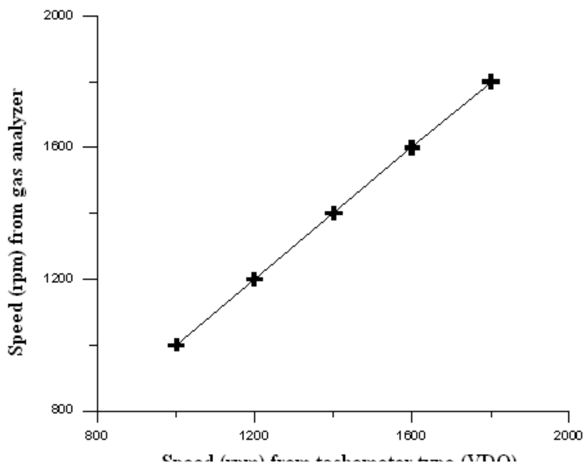

Fig. 5, Tachometer Calibration

The following relationships were used to calculate engine performance:-

For Brake Power (Bp) $= \frac{2\pi * N * T_b}{60*1000}$ (kW).. (1)

Where:

T_b = Brake torque (N.m).

N = Engine speed (rpm).

Fuel consumption (L/h)

$$\text{Fuel consumption} = \frac{V_f}{\text{time}} \quad \text{(L/h)} \ldots\ldots (2)$$

V_f = volume of fuel consumption in (Liter).

Air Consumption ($\dot{m}_{a,act.}$)

$$\dot{m}_{a,act.} = \frac{5\sqrt{h_o}}{3600} \times \rho_{air} \quad \text{(kg/Sec)} \ldots\ldots (3)$$

h_o = pressure differences between the atmosphere and pressure inside the air box.

ρ_{air} = 1.18 (Kg/m^3) .

Fuel mass flow rate $\dot{m}_f$

$$\dot{m}_f = \frac{V_F}{\text{time}} \times \rho_F \quad \text{(kg/sec)} \ldots\ldots (4)$$

V_F = volume of fuel consumption

Brake specific fuel consumption Bsfc

$$\mathrm{Bsfc} = \frac{\dot{m}_f}{\mathrm{Bp}} \times 3600 \qquad \frac{\mathrm{kg}}{\mathrm{kW.hr}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Brake thermal efficiency

$$\eta_{bth.} = \frac{BP}{\dot{m}_f * LHV} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

LHV= Lower Heating Value

With regards to the experimental procedure, the following steps were done to implement the experimental work:

(i) Preparing the engine and the measurement devices to read the data for natural case and by using magnets.

(ii) Measuring engine speed, brake torque, the pressure differential between the atmosphere and pressure inside the air box, and time of fuel consumed for volume of (100) ml, with and without using magnetic field.

(iii) Measuring the exhausts emissions of (CO, CO_2 and HC) by the gas analyzer from the engine during experimental tests at all the engine tested speeds (from 2000 to 3500 rpm) with and without using magnetic field.

4.Results and Discussion.

Figure (6) represents the amount of fuel consumed (L/h) with the engine speeds for the engine running without and with using magnetic field. The values of fuel consumption (L/h) was increased when the increase in engine speeds. The amount of fuel consumed (L/h) was reduced when magnet was added compared with the case without using magnet by about (2.19%). By using two magnets. The fuel consumption (L/h) was reduced by (5.488%). The effect of increasing the magnetic field is clear, It will affect the molecular grouping resulting in a reduction of fluid viscosity at the macroscopic levels, ionization and realignment of fuel molecule or hydrocarbon chain, the fuel is now actively interlocked with oxygen, hence proper mixing and combustion occurs in (I.C. engine) resulting in a better fuel economy as declared by Van der Waals [2].

The brake thermal efficiency is defined as the ratio of the brake power to fuel consumption and lower heating value (LHV). The brake thermal efficiency indicates the ability of the combustion system to accept the fuel. This will and provide a comparable means of assessing how the efficiency of the energy in the fuel was converted to mechanical output. Figure (7) shows the effect of magnet on brake thermal efficiency for variable engine speed. Brake thermal efficiency was increased when the increase in magnetic field and engine speed was increased. Using one magnet increased the brake thermal efficiency by about (4.7%). When two magnets were used, brake thermal efficiency was increased by (13.5%). The increments in brake power with the increasing of the engine speed and the decrements in

(Bsfc), as previously mentioned are the reasons for increasing the engine brake thermal efficiency.

According to figure (8), it can be seen that the exhaust temperature increased by (1.7%) when the engine speed was increased, and when one magnet was used. And by using two magnets, the increasing was (3.65%) compared with engine was running without magnets. The increments in the exhaust gas temperatures indicated that there was enhancement in combustion within the combustion chamber. The usage of the magnetic field caused the exhaust temperature to be increased.

Figure (9) shows the effect of adding magnetic field to fuel supply pipe for variable engine speeds. CO concentrations increased when the engine speed increased. But it decreased when magnets were used. Increasing engine speed requires increasing the combusted fuel. While adding magnetic field to the fuel supply will enhance the combustion process. This due to the fact that adding magnets will produce complete combustion of the air-fuel mixture. This will result in lowering values of the CO content and increasing the CO_2 content. The decrements in CO concentrations was (3.7%) for adding one magnet and (6.9%) for adding two magnets compared with no magnet.

Figure (10) reveals that the CO_2 concentrations increased when the increase in engine speed , when the magnets were used. The reduction in CO_2 concentrations was about (4.3%) for using one magnet and (9.94%) for two magnets.

Figure (11) manifests the reduction in HC concentrations when magnets were added to fuel supply. The reduction was approximately (4.1%) for using one magnet and (9.1%) for two magnets. The reduction in HC concentrations referred to better combustion with added magnets. While higher HC concentration with higher engine speeds is due to the less available air-fuel mixing time at these speeds.

5.Conclusions

The effects of the magnetic field on the performance and emission of SI engine were studied. The results indicate that:

1- The engine brake specific fuel consumption was reduced with the adding magnets..
2- The engine brake thermal efficiency was improved with the adding magnets.
3- The temperature of exhaust gas was increased with the using of the magnetic field. This is an indication of increasing the temperature of the mixture inside the combustion chamber.
4- Both CO and HC concentrations were reduced in the case of the usage of the magnetic field.
5- CO_2 concentrations were increased with adding magnets to the fuel supply system due to better combustion that leading to reduction in CO and HC concentrations.

6.References

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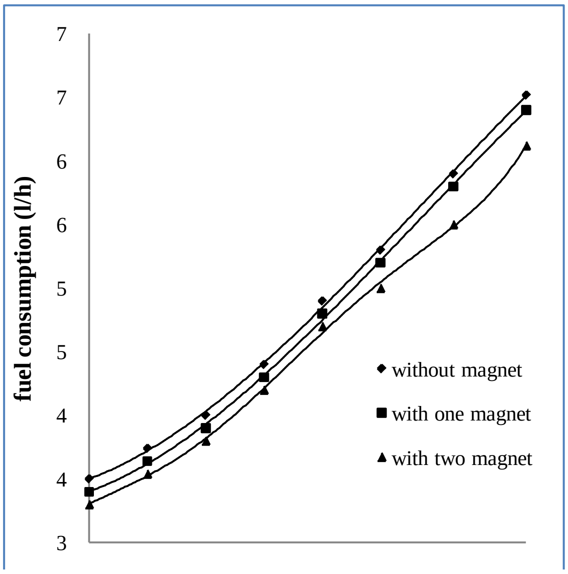

Fig. 6, Magnet effect on brake specific fuel consumption for variable engine speed

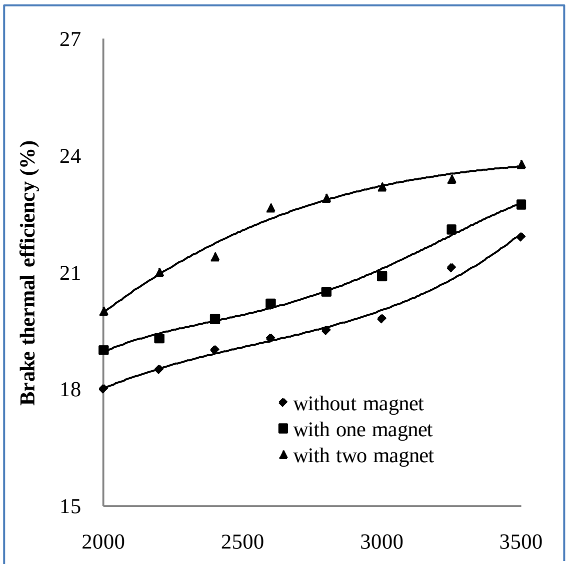

Fig. 7, Magnet effect on brake thermal efficiency for variable engine speed

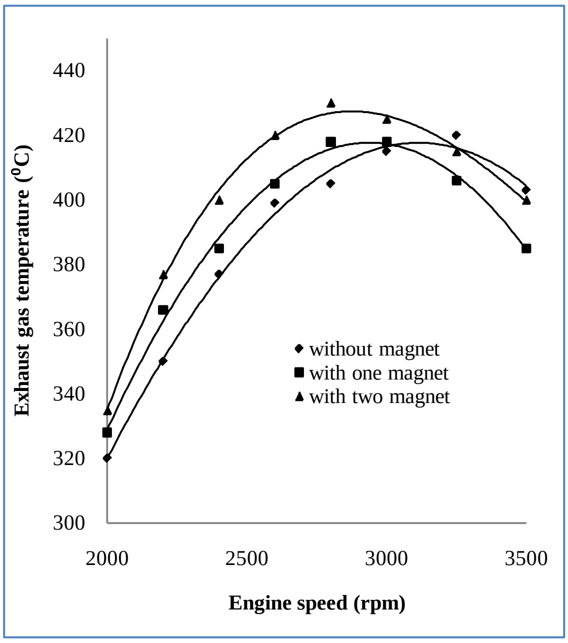

Fig. 8, Magnet effect on exhaust gas temperatures for variable engine speed

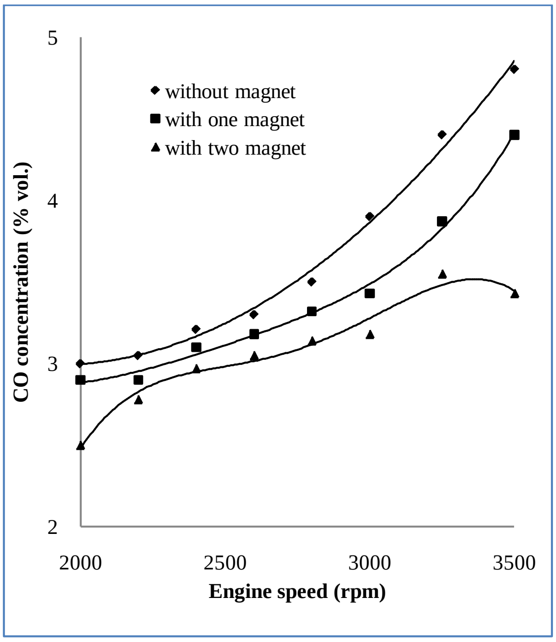

Fig. 9, Magnet effect on CO concentrations for variable engine

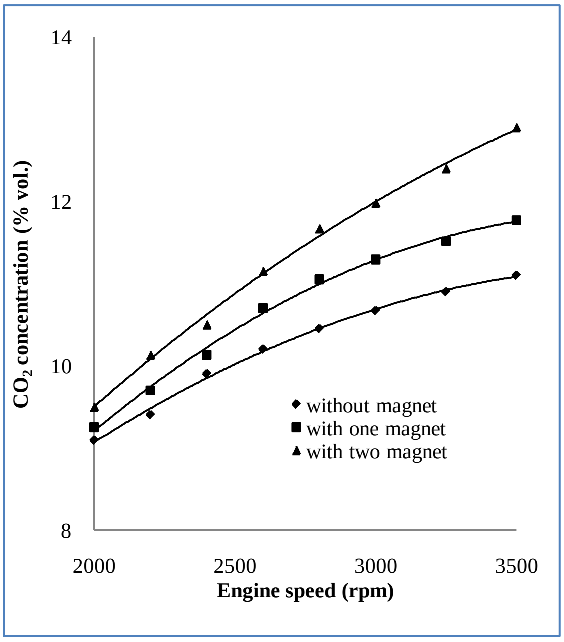

Fig. 10, Magnet effect on CO_2 concentrations for variable engine speed

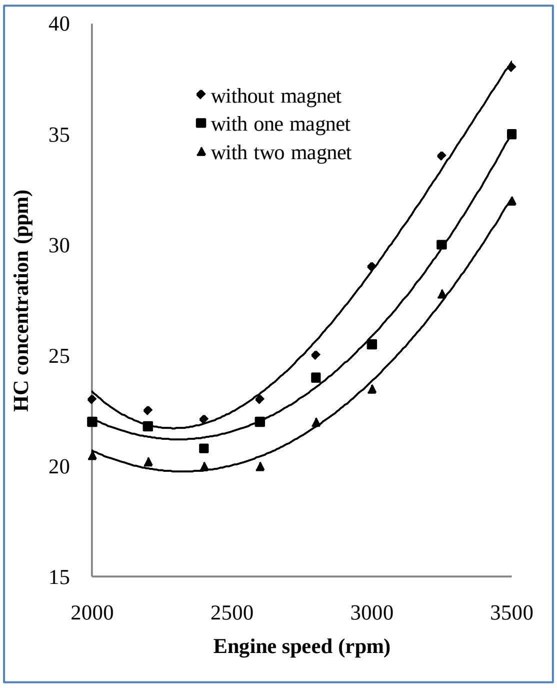

Fig. 11, Magnet effect on HC concentrations for variable engine speed